

Advanced Doppler Radar

- 1c. Describe the parameters, use and limitations of WSR-88D products

Base Products

- Base Reflectivity
 - The WSR-88D produces over sixty different products; base reflectivity is one of them
 - The base reflectivity product generated by the WSR-88D is nothing new; it is simply more colorful, accurate and useful

Base Products

- Theory of Reflectivity
 - The radar simply measures the amount of electromagnetic energy backscattered to the antenna from targets illuminated by the beam
 - The radar must assign a meteorological intensity value to this, which tells us the strength of the storm
 - The radar initially measures the backscattered energy as a measure of power, I.e. 10×10^{-6} milliwatt

Base Products

- This would not mean much to a weather forecaster or observer, and would not help you to do your job
- For this returned energy to be useful to us, it must be processed through, what we call, the radar equation

Base Products

- Assumptions of the radar equation
 - If nature was to always cooperate and conform to our precise mathematical equations, we could easily calculate reflectivity values, referred to as the letter Z
 - Unfortunately, too many variables exist which tend to render our nice equations ineffective
 - The basic radar equation makes many assumptions, which are rarely the case in the natural atmosphere, these assumptions include:

Base Products

- The particles are small, homogenous spheres whose diameters are much smaller than the radar's wavelength (Rayleigh scattering)
- The particles are spread uniformly throughout the contributing region (sample volume)
- Precipitation throughout the entire sample volume is the same (all rain or all snow -- no mixed precipitation)
- The main lobe of the antenna beam pattern is adequately described by mathematical notation

Base Products

- Attenuation and multiple scattering are negligible
- If all assumptions could be met, and if no measurement errors existed, the radar measured Z would conform exactly to the meteorologically defined Z
- Since this is not the case, we must settle for something a little less perfect known as the equivalent radar reflectivity factor, (Z_e)

Base Products

- Equivalent Radar Reflectivity Factor
 - Without bogging down in the murky expanse of a mathematical quagmire, we will look at a simplified version of the equivalent radar reflectivity factor
 - the basic form is:
 - Z_e = equivalent radar reflectivity factor
 - P_r = average returned power in watts
 - R_c = a combination of all known constants in the original long form of the radar equation
 - r = range to target

Base Products

- The radar carefully measures the amount of energy backscattered to the antenna, which gives us power (P)
- It calculates the time between the transmission and reception of each pulse to determine range to target (r)
- Each and every radar, for a given operational mode, has a set of constants such as wavelength, pulse length, antenna design, and other engineering factors, which determine the R_c in the equation

Base Products

- This now provides enough information for the WSR-88D processors to compute a value for Z_e for each sample volume
- The end result is reflectivity measurement for each sample volume, still in the form of a measurement of power

Base Products

- Units of measure: The decibel system
 - Values of Z_e typically span many orders of magnitude
 - The decibel system is used to compare two power values using the logarithm of their ratio
 - The decibel system is useful for comparing power values that differ greatly; such as the difference between the transmitted and returned power
 - Since values of Z_e also vary greatly, it is more useful to express these values in decibels

Base Products

- A very important fact about dBZ comparison is that every change of 3 dBZ corresponds to doubling or halving the equivalent power return
- The displayed colors on the reflectivity product correspond to decibel thresholds

Base Products

- Product description
 - The base reflectivity product displays the intensity of backscattered energy, in decibels, from meteorological targets on a geographical map for each elevation
 - The displays are presented on two 19-inch color monitors, which provide high resolution display capability

Base Products

- Presentation is on a polar coordinate pixel image of reflectivity data in full screen or quarter screen format
- Range and resolution
 - Base reflectivity data is gathered every .13 nm sample volume, out to 248 nm from the radar

Base Products

- The radar displays the reflectivity data at three different resolutions for various range settings
 - .54 nm resolution for the 124 nm range product, takes an average of four sample volumes
 - 1.1 nm resolution for the 248 nm range, this resolution takes the maximum of two .54 resolution reflectivity values
 - 2.2 nm resolution for the 248 nm range, this resolution takes the maximum of two 1.1 nm resolution values

Base Products

- One product available for each resolution and each elevation angle (dependent on particular VCP in use)
- Data levels are lower bound thresholds available in 8 or 16 levels
 - Current values are set at 5 -75 dBZ for precipitation mode
 - -28 - +28 dBZ in clear air mode

Base Products

- The product legend exists on the right side of all WSR-88D products
 - The legend contains valuable information about the radar, the product, and display information. It includes:
 - » Product name and ID number
 - » RDA ID
 - » Time and date of scan
 - » Data levels (color values for decibel values)
 - » Elevation angle
 - » Maximum dBZ detected by the radar
 - » Radar position

Base Products

- » Radar elevation above MSL
- » Radar operating mode
- » Product range and resolution

Base Products

- Use of the base reflectivity product
 - The reflectivity product will give radar operations the ability to recognize numerous classical weather features
 - Precipitation mode
 - High reflectivity storm cores
 - Strong reflectivity gradients
 - Embedded thunderstorm activity
 - Hook echoes
 - Line echo wave pattern (LEWP)
 - Bounded weak echo region (BWER)

Base Products

- Clear air mode: you will be given the opportunity to see features from optically clear air
 - Dry frontal boundaries
 - Old outflow boundaries from recent storms
 - Inversions
 - Sea breezes

Base Products

- Limitations of base reflectivity
 - Ground clutter and anomalous propagation can contaminate data
 - The beam's height above the ground increases with range, causing overshooting of distant targets
 - Beam broadening may cause small features (such as hook echoes) undetectable at longer ranges
 - Side lobe contamination, which can cause false echo tops and false intensities

Base Products

- Base Velocity
 - Base velocity is the average velocity of the airflow parallel to the radar beam within the sample volume

Base Products

- Doppler theory review;
 - Doppler shift
 - When electromagnetic energy is transmitted and strikes a target moving toward (negative or inbound) the radar, it returns as a positive phase shift in the returned energy
 - When electromagnetic energy strikes a target moving away (positive or outbound) from the radar, it is returned as a negative phase shift in the returned energy
 - When electromagnetic energy strikes a stationary target, or one moving perpendicular to the beam, no phase shift occurs
 - It is the Doppler shift, which allows the computer to determine the radial velocity of the sample volume

Base Products

- Radial velocity is displayed using different colors for inbound and outbound velocities
 - Cool colors (e.g. green, blue) are used to depict inbound velocities and are expressed as negative values
 - Warm colors (e.g. red, yellow) are used to depict outbound velocities and are expressed as positive values
 - Varying shades of the respective colors are used for indicating magnitude, with brighter shades usually associated with the strongest velocities

Base Products

- Radial velocity review
 - Doppler radar only measures the radial component of the wind
 - When using the term radial velocity, we mean that the WSR-88D is only measuring the wind velocity moving directly down the beam
 - Examples:
 - » If the wind is blowing from the west at 50 knots and the antenna is pointing toward 270° , then we are seeing the full component and the WSR-88D measures all 50 knots

Base Products

- » If the wind is blowing from the west at 50 knots and the antenna is pointing at 315° , only a portion of the wind is actually moving directly down the antenna and the WSR-88D only measures 35 knots (cosine of 45° times 50 knots)
- » Still using a westerly wind at 50 knots, except this time the antenna is pointing at 360° resulting in no phase shift and the WSR-88D senses no wind or zero velocity

Base Products

- By the radar detecting only the radial velocity a distinct line of zero Doppler velocity develops
- This line of zero Doppler velocity is known as the Doppler zero line and is an important factor in determining wind direction.

Base Products

- Product description
 - The base velocity product displays the mean radial velocity data as an image
 - A separate product is available for each elevation angle in the current volume coverage pattern (VCP)
 - Presentation of velocity data is on a polar coordinate map, available in full screen or quarter screen format
 - One product is available for each resolution, per elevation angle

Base Products

- Data levels are lower bound thresholds, available in 8 data levels (-10 knots to +10 knots) or 16 data levels (-64 knots to +64 knots)
- Resolution and range
 - .13 nm x 1° resolution out to a 32 nm radius displays all sample volumes
 - .27 nm x 1° resolution out to a 62 nm radius, displays the first of two sample volumes
 - .54 nm x 1° resolution out to a 124 nm radius, displays the first of four sample volumes

Base Products

- Product legend is displayed on the right side of the product
 - Information contained in base velocity product's accompanying legend is the same as reflectivity
 - The only exception is the maximum detected by the radar is given for both outbound and inbound

Base Products

- Use of the base velocity product
 - Precipitation mode
 - Tornado Vortex Signature (TVS)
 - Mesocyclone identification
 - Rotation
 - Thunderstorm Divergence/Convergence
 - Fronts

Base Products

- Clear air mode detection gives you the ability to see things in the optically clear air, and with great sensitivity, going down to -28 dBZ
 - Flight level winds
 - Turbulence
 - Old thunderstorm outflow boundaries
 - Inversions

Base Products

- Limitations of the base velocity product
 - Ground clutter and anomalous propagation can contaminate data
 - Product data levels may obscure features
 - Range folded, velocity aliased or data incorrectly dealiased, may cause incorrect interpretation
 - Data coverage is limited by the amount of scatters in the atmosphere
 - Velocities are relative to the RDA location - not the PUP location
 - For effective severe storm analysis, multiple elevation angles must be used

Base Products

- Base Spectrum Width product
 - Theory of spectrum width
 - Spectrum Width is a measure of the velocity difference or spread within a sample volume
 - The Spectrum Width product provides information from which you can make determinations about various atmospheric occurrences such as turbulence, wind shear, and the early stages of convective development
 - It provides assistance in your analysis of atmospheric motions

Base Products

- The Spectrum Width product is best used in conjunction with velocity and reflectivity products
- Particles in a Sample Volume
 - Within a sample volume there are many particles of varying size, shape and composition moving in different directions and speed
 - Doppler radar doesn't sense each individual motion, but rather, a combination of all the motions
 - This combination of different motions, or dispersion, is what the Spectrum Width measures

Base Products

- Normally, spectrum width is directly proportional to the amount of shear or turbulence within the sample volume
- The ideal distribution of Doppler shift (frequency) versus returned power looks like a bell curve when plotted on a graph
- The maximum returned power is usually at the frequency of the backscattered energy from the largest meteorological targets
 - First, spectrum width estimates are most influenced by the largest scatters since they return exponentially (D^6) more energy back to the radar
 - Second, the largest scatters are the least affected by turbulent motions and tend to be centered closely around the environmental winds

Base Products

- The weaker returned power at the wings of the spectrum are from targets that are generally smaller and more effected by small disturbances in the environmental flow
- Since greater forces are required to move larger targets, the dispersion of the right and left wings of the spectrum can be interpreted as the amount of gustiness and/or turbulence observed by the radar
- Extremely small targets in a calm environment result in weak, narrow spectra
- Large targets in a turbulent environment produce strong, wide spectra
- The width of the spectra is the measured spectrum width in knots and is what we see displayed on the product

Base Products

- Product description
 - The Spectrum Width product displays velocity spectrum width data on a polar coordinate map and is available for any valid elevation angle (dependent on the particular VCP in use)
 - Presentation is in full screen or quarter screen format
 - One product is available for each resolution and elevation angle
 - Base Spectrum width is only available in eight data levels

Base Products

- Data levels are lower bound thresholds ranging from zero to 19 knots
- Resolution and range
 - .13 nm x 1° resolution out to 32 nm radius, displays all sample volumes
 - .27 nm x 1° resolution to 62 nm radius, displays the first of two sample volumes
 - .54 nm x 1° resolution to 124 nm, displays the first of four sample volumes
- Product legend exists on the right and is the same organization as the other base products

Base Products

- Use of Spectrum Width
 - Fronts
 - Embedded convection
 - Turbulence Melting level
 - Gust fronts or outflow boundaries

Base Products

– Limitations

- The Spectrum Width product is not reliable in all cases
- Other products, such as the Skew-T diagram and centrally prepared charts, should be analyzed in addition to the various WSR-88D products available
- Limitations from beamwidth
 - Increasing beamwidth with range results in larger sample volumes with range
 - Larger sample volumes contain more particles thus an increased likelihood for variability
 - Detecting more variability results in higher Spectrum Width values

Base Products

- Limitations from antenna rotation rate
 - Slower rotation allows more sequential samples of a given area, thus a more reliable estimate (lower widths)
 - Faster rotation results in less reliable estimate and generally higher Spectrum Widths
- Limitations from weak signal return
 - This signal may be near the noise level
 - Spectrum width may be erratic
 - Usually spectrum width values high in this situation

Base Products

- Interpretation of the Spectrum Width products is not straightforward
 - Inferences can be made from width values, however, difficult to interpret
 - Requires operator skill and experience

Derived Products

- Composite Reflectivity Product
 - Theory of Composite Reflectivity
 - The Composite Reflectivity product, abbreviated CR, contains basically the same information we find in the Base Reflectivity product
 - One very important difference exists; Composite Reflectivity displays information collected from all the elevation angles, not just one

Derived Products

- Comparison of Base and Composite Reflectivity
 - The data on the Base Reflectivity product are collected from a single slice of the atmosphere
 - A problem exists when there are stronger reflectivities above or below the slice you are viewing
 - CR solves this problem
 - As a WSR-**D operator, you are interested in detecting a potentially severe thunderstorm, so you want your attention drawn to any strong echoes of about 40 dBZs or greater
 - The CR product can alert you to the existence of these strong echoes

Derived Products

- Identification of Strongest Reflectivities
 - The CR product compares all the reflectivities above a location on the ground and identifies the strongest
 - All the other reflectivities at this location are discarded and the remaining reflectivity of 50 dBZ is displayed
 - The CR does this for the entire area of radar coverage and displays the strongest reflectivity found over each individual location
 - The end result is a display of only the strongest reflectivities observed over the radar coverage area
 - Which easily allows the identification of the strongest echoes in the radar coverage area

Derived Products

- Important considerations about composite reflectivity
 - The dBZ value displayed for any location could have come from any of the elevation slices or heights
 - Values displayed side-by-side also could have come from different elevation slices
- Side by Side reflectivity values
 - The CR product displays the strongest reflectivities regardless of the height or elevation scan in which they were detected
 - Because of this, reflectivity values displayed side by side by the CR product may actually be detected at different heights

Derived Products

- Volumetric Products
 - Composite reflectivity requires data from every elevation scan
 - Unlike base reflectivity product an image was available after each elevation scan
 - Composite reflectivity not available until after the RDA has completed one entire volume scan - all elevations from lowest to highest
 - Since the entire “volume” of the radar coverage must be scanned before the CR product can do its work, we call CR a volumetric product

Derived Products

- Volumetric Overlays
 - Composite reflectivity is a good product for you to display volumetric overlays
 - Certain products/overlays may be paired together so they are both displayed simultaneously
 - For instance, if you paired base reflectivity with a volumetric overlay, it could cause the product to be displayed without the volumetric overlay
 - You can ensure this does not happen by pairing volumetric products with volumetric overlays

Derived Products

- Product Description

- CR product displays an image of the maximum reflectivity above that area
- The product is available in two versions – one with 8 data levels and one with 16
- One product is available for each resolution per volume scan
- Data levels are lower bound thresholds available in 5 – 75 dBZ for precipitation mode and -28 to + 28 dBZ in clear air mode

Derived Products

- Presentation is on a geographical map of reflectivity values in full screen or quarter screen format
- Resolution and range
 - .54 x .54 nm out to 124 nm radius
 - 2.2 x 2.2 nm out to 248 nm radius
- The product legend exists on the right side and is similar to other products

Derived Products

- Combined Attributes Table
 - Displayed on the top of each product is an overlay, it listed the output of several storm algorithms
 - The attributes of up to 100 storms can be listed in this table
 - Only four storm attributes are visible at any one time
 - The page attributes function allows the remaining storms to be viewed

Derived Products

- Storm information from four meteorological products are included in the table, they are:
 - » Hail Index
 - » Mesocyclone
 - » Tornado Detection Algorithm
 - » Storm Cell Tracking Information (STI)
- If one algorithm fails, the attributes table will not accompany the product
- The attribute table is available for full screen CR display only
- Storms are ranked in order of severity in the attributes table

Derived Products

- The highest priority cell would be the one containing the TVS, then ETVS, Mesocyclone, three dimensional shear, two dimensional shear, probability of severe hail, probability of hail, and finally cell- based VIL
- Selecting a storm using the attributes table
 - » You have the ability with the attribute table to select, with the cursor, a storm of interest, and use this geographic point for many products
 - » By using the graphic tablet and puck, you select the storm you are interested in by clicking on its storm ID listed in the table
 - » This geographic location can then be used for cell trends, cursor home define, recenter/magnify, and AZRAN select

Derived Products

- No algorithm is used to generate the CR product; a single Task File is employed

Derived Products

- Use of the Composite Reflectivity (CR) product
 - CR is a quick way to get the “total picture”
 - First and foremost, it is an attention getter; all of the strongest reflectivities detected by the radar are simultaneously displayed
- Limitations
 - Composite Reflectivity is made up of information that comes from the Base Reflectivity products: many of the same limitations, which affect the quality of reflectivity data, also cause problems with CR
 - For instance, ground clutter and anomalous propagation can cause problems in the reflectivity displays and, therefore, may also give non-weather related values to the CR product

Derived Products

- The following is a list of more unique limitations:
 - Height data is lost
 - » Echoes aloft cannot be distinguished between those extending to the surface
 - » Pattern recognition is basically meaningless
 - » Features that depend on horizontal consistency may not be recognizable since CR may present data from different altitudes side by side

Derived Products

- Echo layers such as the melting level (bright band) appear as multiple rings around the RDA
 - » One layer is detected by various elevation slices at different ranges
 - » These rings tend to obscure other more useful data

Derived Products

- Other limiting factors
 - » As with reflectivity, values tend to be 5 to 15 dBZ higher than previous radars
 - » Algorithm pauses cause loss of combined attributes table and overlays
 - » Only four storms can be listed in the visible attributes table

Derived Products

- Layered Composite Reflectivity Maximum (LRM)
 - Theory of Layered Composite Reflectivity Maximum
 - The Layered Composite Reflectivity Maximum (LRM) is comparable to the Composite Reflectivity in that it gives the maximum reflectivity for a particular grid box
 - The major difference is that the CR product is produced by using the entire volume scan, which makes it difficult to determine the approximate altitude of a particular reflectivity value
 - The LRM uses three layers: LOW, MID, and HIGH in the production of the product

Derived Products

- Layered Products
 - The LRM is a layered product, which means it uses a combination of elevation slices to acquire data for an operator selected layer
 - Similar to the Composite Reflectivity Product, the LRM will use the maximum reflectivity values in a vertical column
 - The LRM will only use the elevation slices that fall within the heights specified for the layer product

Derived Products

- The MID and HIGH layers are set altitudes and cannot be modified
- The lower limit of the LOW altitude may be modified by the UCP, with approval by the URC
 - » The layer has to remain at least 6,000 feet thick, and changes affect all associated users connected to the RPG
 - » This feature is extremely useful for mountainous stations

Derived Products

– Product description

- The LRM displays maximum reflectivity data for layers defined as LOW, MID or HIGH
- This product is only available as an 8 data level product
- One product is available for each layer, per volume scan
- Lower bounded thresholds are set at 5 to 57 dBZ
- Default layers are set at LOW (SFC to 24 kft), MID (24kft to 33 kft), and HIGH (33 kft to 60 kft)

Derived Products

- Presentation is on a geographical map in full or quarter screen
- Resolution and range is 2.2 x 2.2 nm for 248 nm x 248 nm coverage
- The information is the same in the product legend for other reflectivity products with one exception, the LRM lists the altitude of the product instead of elevation slice

Derived Products

- Use of the Layered Composite Reflectivity Maximum
 - The LRM is useful in giving you a quick look at significant reflectivity values for a specified layer
 - Enables you to quickly identify the stronger storms and those areas with a greater propensity for convection

Derived Products

- Convective Regimes
 - The LRM is an excellent way of tracking the intensity trends of convection
 - If an operator notices reflectivity values or the size of an area increasing rapidly in the MID layer, with an increase of reflectivity values in the LOW layer, the storm is decaying and has the potential for a microburst
 - Pulse convection or rapidly building isolated thunderstorms also show up well on the LRM product
 - Given the ability to raise the lower boundary on the LRM may assist forecasters in the identification of pulse type storms, which push stronger reflectivities higher up than non-severe single cell thunderstorms

Derived Products

- Correction of Reflectivity Maximum with Height
 - The height of the maximum reflectivity can be used to identify the severity of storms
 - A storm containing strong dBZ values (≥ 50 dBZ) in the HIGH altitude layer indicates an intense updraft and strong likelihood for severe weather
 - High reflectivity values in the MID altitude layer can be correlated with heavy precipitation in tropical regimes, as well as in stratiform regimes

Derived Products

- Limitations
 - The LRM uses only those elevation angles that fall within the altitude of the layer specified
 - The LRM will be adversely affected at distant ranges from the radar, where the layer may only encompass one or two elevation slices
 - At close ranges, MID and HIGH layer altitude products are ineffective due to the cone of silence
 - As with the CR, individual characteristics of severe storms may be lost due to the LRM's use of several elevation slices
 - Signatures such as hook echoes, BWERs and WERs may not be detectable. For this reason, compare the LRM with other products before drawing conclusions

Derived Products

- Vertical Integrated Liquid
 - Theory of VIL
 - The VIL product is the end result of analysis performed by the VIL algorithm
 - The function of the VIL algorithm is to estimate the amount of liquid water contained in a storm, then display that value in a graphical form for your use
 - The magnitude of the VIL value in convective situations is related to the strength of the updraft, which is related to the severe weather potential of the storm

Derived Products

- The VIL product is an excellent tool which can enhance your ability to distinguish severe from non-severe storms
- Vertical Integration
 - The VIL algorithm converts weather radar reflectivity data into liquid-water content values
 - These values are based on theoretical studies of drop size distributions and empirical studies of the relationship between the reflectivity factor and liquid-water content
 - The algorithm uses a mathematical equation to make these relationships
 - This VIL value is simply an indication of how much water is contained in the storm

Derived Products

- Process of Integration
 - VIL are calculated for each location in the radar coverage and for each elevation scan
 - Then the VIL algorithm just adds all the values together that are in a vertical column
 - This gives you the integrated part of VIL

Derived Products

- However, before integrating these values, a correction must be applied for hail
 - » This is due to the reflectivity returns from hail, which can fluctuate rapidly and cause unrealistic water equivalency measurements
 - » To compensate for this the algorithm truncates all reflectivities of higher than 55 dBZ, to 55 dBZ
 - » Essentially, setting a maximum value for reflectivity and making VIL measurements more realistic and manageable

Derived Products

- The end result is that for any location on the earth, you now have an estimation of how much liquid water is suspended in the atmosphere above that point
- VIL is also a volumetric product like CR, which requires a complete volume scan before the product can be displayed

Derived Products

- Units of VIL
 - Since we are calculating the amount of water in a vertical column, we need some type of unit which specifies mass per volume
 - Values of VIL are in metric units of kilograms per square meter (kg/m^2)
 - For each elevation slice, these values are linear, but once the vertical column is integrated, they represent a volumetric measure

Derived Products

- Product description
 - The VIL product displays its values as a graphic image
 - The product displays 16 data levels
 - Updated once per volume scan with data levels ranging from at 5 – 70 kg/m²
 - Presentation is on a Cartesian pixel image of VIL values in full screen or quarter screen format
 - Resolution and coverage is 2.2 x 2.2 nm out to 124 nm radius
 - Product legend is on the right side, in two formats full screen and quarter screen

Derived Products

- Limitations

- Seasonal and diurnal variations

- VIL values change with the seasons and from location to location
- More specifically, VIL values change from diurnal and air-mass variations as well
- Under different weather conditions, the minimum VIL value associated with severe weather varies by different amounts - but general trends can be expected
- Warm, moist air masses tend to exhibit higher VIL values during severe weather occurrences

Derived Products

- Cool, dry air masses produce much lower values during severe weather occurrences
- You need to know the typical values for your specific location and synoptic situation in order to use VIL effectively

Derived Products

- Tilted storms
 - The VIL algorithm calculates values for grid boxes (stacked in the vertical) that are 2.2 x 2.2 nm
 - A storm that is strongly tilted may not have all of its vertical extent within the same stack of grid boxes
 - The VIL algorithm does not know that the storm is tilted, it just follows the same rules it always uses
 - In a bad case, the algorithm could be adding up “empty” boxes, and thus a low value of VIL would be reported for a large storm

Derived Products

- Fast moving storms
 - The same problem of low VILs occurs with storms that move much faster than the average of the other storms present in the radar coverage area
 - In this case, the VIL algorithm is again calculating values using a vertical stack of boxes
 - It takes at least 5 minutes for the radar to finish a scan from the lowest elevation to the highest
 - A fast moving storm may have traveled enough to move through and even exit the stack of boxes, thus fooling the VIL algorithm
 - The result is an underestimation of the true severity of the storm
 - The VIL algorithm, or any other algorithm for that matter, works best when storms closely approximate the norms on which the algorithm was based

Derived Products

- Data reliability
 - You should always remember that VIL is calculated from reflectivity data
 - Factors causing errors in reflectivity also cause errors with VIL
 - Ground clutter gives unrepresentative values of reflectivity at low elevations, which in turn will lead to erroneous VIL values

Derived Products

- VCP limitations
 - Non-vertical contiguous Volume Coverage Patterns may also affect the accuracy of the VIL estimation for a given storm
 - Due to data gaps in the VCPs some portions of the atmosphere remain unsampled
 - This effect will be greater for VCP 21, than for VCP 11, since there are more data gaps
 - As a storm moves through these gaps, VIL values tend to rise and fall quite dramatically
 - The result will be erratic, possibly unreliable, VILs

Derived Products

- Use of the VIL algorithm
 - The VIL product is useful to you as a way to distinguish between severe and non-severe storms
 - The VIL product shows a special sensitivity to the degree of storm severity

Derived Products

- Severe Weather Probability (SWP)
 - Theory of SWP
 - The Severe Weather Probability product, abbreviated SWP, provides you with an objective assessment of a storm's potential to produce severe weather
 - The SWP's sole input is VIL
 - Computation of SWP
 - SWP is a volumetric product and is calculated for specific locations above the earth's surface
 - A grid box is theoretically placed on the surface of the earth and a SWP is calculated for the space above that box
 - The SWP equation relates VIL values to the occurrence of severe weather
 - As it now stands, the regression equation for SWP was developed from springtime data collected in Oklahoma
 - New equations must be developed for meteorological conditions representative of other seasons and geographical locations as well

Derived Products

- Ground Truth Information
 - Relating VIL values to the occurrence of severe weather is done by reviewing VIL data and correlating these with past weather results
 - This is called ground truth information
 - This process is necessary in order to derive a correlation or relationship, in the form of a statistical equation, which relates VIL data to ground truth reports of severe weather
 - The statistical equations differ for various radar sites and different weather regimes
 - When your radar is delivered, modifications of this equation may have already been done and be part of your radar's software
 - If not, later modifications can be made by the UCP operator upon approval by proper authority
 - With a good equation in place, the RPG inputs values of VIL to the SWP algorithm and begins its calculation of the probability of severe weather occurrence

Derived Products

- SWP grid boxes
 - Similar to the VIL product, the SWP product uses a set of grid boxes to develop SWP values
 - The SWP grid box is larger than the VIL box
 - The number of VIL grid boxes used to constitute a cell and the coefficients used in the equations are site adaptable parameters
 - The default SWP grid box size is 15.1 x 15.1 nm
 - The default coefficients were derived from Oklahoma data and are most likely not ideal for your location
 - Additional data for your location must be collected and a new statistical equation calculated to determine the best coefficients for use in your geographical area

Derived Products

- Fast moving or strongly tilted storms
 - Knowledge of the size of your SWP grid box is important
 - Even though the SWP is calculated from the VIL data, the behavior or change with time of the SWP may be different from VIL since the grid box size is different
 - Since your SWP grid box size is much larger than the VIL box size, fast moving or the tilting storm will still be contained in the same SWP box
 - The drop in VIL may not be reflected by a proportional drop in SWP

Derived Products

– Product Description

- The Severe Weather Probability (SWP) product provides a mapped display of values calculated from the SWP equation
- The product can be displayed independently or as an overlay to other displays
- The displayed SWP values are assigned to the centers of the defined VIL cells
- One product is available per volume scan with three data levels
- Presentation is on a geographical map of SWP values (percentages) with each value displayed at the center of its corresponding VIL cell

Derived Products

- The product may also be displayed as an overlay of mapped SWP values
- Displayed values are color-coded
 - Values greater than or equal to 1% but less than 35% are light blue
 - Values greater than or equal to 35% but less than 50% are yellow
 - Values greater than or equal to 50% are bright red
- Resolution and range
 - Resolution is set at a default of 7 x 7 VIL boxes (15.1 x 15.1 nm)
 - Range is out to 124 nm from the RDAR
- The product legend is displayed on the right side of the product, in full or quarter screen format

Derived Products

– Limitations

- SWP values are calculated from VIL and, therefore, are affected to some degree by all the same factors which affect VIL
- If you suspect problems with VIL, you should also assume that SWP values are also unreliable
- SWP is based on a statistical relationship
 - Occasionally current conditions do not match those of the historical data set with which the technique was developed
 - The absolute SWP values are not accurate on these occasions
 - However, relative SWP values may still be useful, I.e. a storm with an SWP of 85% is probably more dangerous than one with 20%, all other factors being equal

Derived Products

- Echo Tops
 - Theory of Echo Tops
 - The ET product indicates the heights of echoes, in thousands of feet above mean sea level (MSL), by using different colors to represent heights
 - The echo top height is of particular interest to those supporting aviation
 - The ET product, like CR, is a volumetric product which uses information gathered in the entire volume coverage pattern to display a final end product
 - Any echo returns providing a reflectivity return stronger than an adaptable threshold value (current default is 18.5dBZ) are considered by the product's algorithm

Derived Products

- Echo Top Height Calculations. The ET algorithm computes echo top height in the following manner
 - First, the horizontal area underneath the radar coverage pattern is divided into 2.2 x 2.2 nm grid boxes
 - The radar begins with the first (lowest) elevation scan and whenever a reflectivity greater than 18.5dBZ is detected, the height of that reflectivity is assigned to the appropriate grid box
 - The first elevation scan, any 18.5dBZ reflectivity detected is the current “echo top”
 - Next, a second elevation slice begins and whenever 18.5 dBZ reflectivity is detected, a new echo top is assigned to that box

Derived Products

- Whenever a 18.5 dBZ reflectivity is detected at a higher elevation, the height of the new reflectivity replaces the old value and becomes the new ET for that stack of grid boxes
- This process continues repeatedly for each elevation slice until the highest slice is completed
- The final height entered for a stack of grid boxes remains as the echo top

Derived Products

– Product Description

- The ET product is a reflectivity based product depicting the level of the highest echo detected over a specific geographic region
- ET provides a quick look over a large area and includes all elevation angles
- The ET product uses 16 data levels to represent categories of echo top heights
- All heights are referenced to mean sea level (MSL)
- One product is available per volume scan with data levels ranging from 5,000 to 70,000 feet

Derived Products

- Presentation is on a Cartesian pixel image of echo top heights available in quarter screen and full screen formats
- Resolution and range is 2.2 x 2.2 nm out to 124 nm radius
- The product legend exists on the right side in full or quarter screen format

Derived Products

– Limitations

- Echo tops are not the actual cloud top
 - The echo tops displayed by the WSR-88D are probably NOT the actual cloud top
 - The ET algorithm discards reflectivities below a preset threshold (the default is 18.5 dBZ)
 - The actual cloud tops will extend beyond the heights the ET product displays
 - A minimum significant reflectivity threshold needs to be established before you can use ET to safely estimate actual cloud tops
 - This would require modification of the 18.5 dBZ default value, and would effect all that use the radar
 - By the default settings, the echo tops product is essentially the maximum vertical extent of precipitable echoes
 - A general correlation between decibels and clouds is 5 dBZ

Derived Products

- Stair-step Pattern
 - Cone of silence
 - » The antenna's maximum elevation angle is 195° , and thus a limited height capability close to the radar
 - » At these close ranges, the product reports a limited ET no matter how tall the actual storm
 - » The result is a series of heights encircling the RDA site, with increasingly higher echo tops farther from the antenna
 - Beam broadening and uniform tops
 - » A second cause to this stair-step pattern and is most easily observed in weather systems with uniform tops
 - » Since the beam is spreading vertically and horizontally with distance, the resolution of the beam is decreasing with range
 - » The result is possible errors in the ET heights

Derived Products

- Stair stepping by VCP
 - » The VCP in use can also add to or increase the errors with ET heights
 - » The data gaps associated with a given VCP can increase the “stepped” appearance, when actual echo tops exist between the gaps
- Example of the stair stepped pattern
 - » The ET product plots echo tops at the height of the center of the beam
 - » This happens regardless of whether the echo is detected throughout the beam, at the very center of the beam, or from just the lower edge of the beam
 - » The result is identical heights displayed even though some variation is actually occurring

Derived Products

- » When the next higher elevation is used, another set of identical heights is displayed
- » This effect causes a sudden jump from one height to the next higher height, at the same range from the RDA
- » This uncertainty in the accuracy of height measurements can be quite significant (at 124 nm, errors of 6,500 ft are possible)

Derived Products

- Data Contamination
 - » The ET product also does not correct for data contamination from side lobes
 - » This contamination causes overestimation of tops in areas of strong reflectivity

Derived Products

- Storm Total Precipitation (STP) Product
 - The STP product is one of three precipitation products that the WSR-88D generates
 - The others are the One Hour Precipitation Product (OHP), the Three Hour Precipitation Product (THP), and the User Selectable Precipitation (USP) product
 - The STP product gives us information on the total amount of precipitation over a certain amount of time

Derived Products

- Theory of Storm Total Precipitation
 - The STP product provides us with an objective assessment of rainfall rates over a longer period of times than the other three precipitation products
 - It is valuable to the National Weather Service for flash flood warnings
 - The STP extends from initial detection of precipitation within 124 nm until one hour after no precipitation is detected within 124 nm
 - It may exceed 24 hours
 - The product displayed is the total rainfall accumulation

Derived Products

- It becomes available from the first volume scan of detected rainfall
- It then updates precipitation accumulations each volume scan
- The precipitation accumulations are most accurate for large scale precipitation systems

Derived Products

- Product Description

- The STP provides a graphic image of continuously updated precipitation accumulations within 124 nm of the radar
- The storm total precipitation is defined as the total precipitation accumulated since the last one hour break in significant precipitation over the total area of coverage
- One product is available per volume scan with a 16 data level range of 0 - ≥ 25.4 inches
- Presentation is on a pixel image of precipitation accumulation available in quarter screen or full screen format

Derived Products

- Resolution and range is $1.1 \times 1^\circ$ out to 124 nm radius
- The product is centered at the radar location
- The product legend is displayed on the right side in one of two forms, full or quarter screen

Derived Products

- Use of Storm Total Precipitation
 - Aids in the monitoring of total precipitation accumulations, regardless of duration
 - Estimation of total basin run-off due to a single storm
 - Estimation of basin saturation due to previous rainfall events
 - Evaluation of flood reports
 - Post storm analysis

Derived Products

- Limitations

- Extended WSR-88D system outages during precipitation events compromises the data
- Breaks in precipitation of more than one hour resets the system
- Non-precipitation reflectivity, such as clutter or anomalous propagation, may contaminate data
- The algorithm does not account for snow or frozen precipitation, bright-bands, reflectivity gradients, or attenuation
- Small scale or isolated convection degrades accuracy

Derived Products

- Storm Relative Mean Radial Velocity Map (SRM) and Storm Relative Mean Radial Velocity Region (SRR)
 - Theory of Storm Relative Mean Radial Velocity
 - The SRM/SRR product provides a clearer look at Base Velocity products
 - This is done by subtracting storm motion from the Base Velocity product
 - The SRM/SRR aid forecasters in determining the convective currents and intensities within storms
 - Problems arise when storm motion obscures actual values on velocity products

Derived Products

- The SRM/SRR products simply make the storms look like they are standing still
- This product provides a detailed look at potential severe weather by balancing out the velocity couplets and making the signatures more readily identifiable

Derived Products

- Product Description

- The Storm Relative Mean Radial Velocity products provide an estimate of mean radial velocity for:
 - The entire area of radar coverage (to 124 nm) with the storm motion removed (SRM)
 - A small geographic area centered upon or near an identified storm with the storm motion removed (SRR)
- Available upon request for any elevation angle in 16 data levels for:
 - A full coverage velocity product (SRM)
 - A window centered product focused upon a single storm (SRR)
- Presentation is on a polar coordination pixel image of derived mean radial velocity values available in quarter screen or full screen format

Derived Products

- Resolution and range
 - SRM .54 nm x 1° out to 124 nm radius, centered at the radar location
 - SRR .27 nm x 1° and the coverage is a 27 x 27 nm window
 - This product is centered at the user input coordinates
- The product legend exists on the right side in either full or quarter screen format

Derived Products

- Computation of SRM/SRR
 - Data values displayed are the maximum for a given resolution
 - For the SRR, data resolution is $.27 \text{ nm} \times 1^\circ$, but the value displayed is the maximum value contained in a pair of 0.13 nm gates
 - For the SRM, data resolution is $.54 \text{ nm} \times 1^\circ$, but the value displayed is the maximum value contained in four $.13 \text{ nm}$ gates

Derived Products

- The SRM/SRR products are dependent upon the Storm Tracking Algorithm
 - If it is in error, then the SRM/SRR products are in error off unless the user inputs correct direction and speed values
 - The input storm direction and speed to the SRM/SRR are as follows:
 - For SRR, storm motion defaults to the motion determined by the storm track algorithm for the centroid NEAREST the product center if a storm is identified within the 27 x 27 nm window
 - Otherwise, it will default to the SRM value when no storms are identified within the window
 - For SRM, storm motion defaults to the AVERAGE track determined by averaging ALL tracks calculated by the storm track algorithm

Derived Products

- Velocity Azimuth Display (VAD) / (VAD Wind Profile (VWP))
 - Theory of VAD/VWP
 - Now, with VAD/VWP, we are not limited to two upper-air soundings a day, but have vertical wind profiles available every 5, 6 and 10 minutes (depending on VCP)
 - Reading the VWP display is quite simple, the display is similar to the wind profile displayed on a Skew-T
 - In order for the VWP to be displayed the radar must be able to determine the actual winds for each altitude

Derived Products

- The VAD Algorithm
 - The VAD algorithm is used to obtain the vertical profile of horizontal wind speed and direction for the region of the atmosphere surrounding a WSR-88D
 - The VAD Wind Profile is produced from this analysis
 - The radar scans 360° and gathers velocity data measurements
 - All other radar velocity measurements are the radial components only

Derived Products

- Gathering the Data
 - The VAD algorithm uses velocity and reflectivity data that were collected and processed by the RDA and RPG
 - Based on parameters set by the UCP, the algorithm gathers data from defined ranges and altitudes to be processed
 - The algorithm uses only data needed to determine the wind direction and speed for all 30 levels required by the VWP, and any other levels required by associated user RPS lists
 - To determine the wind direction and speed for each level, the algorithm constructs a radial velocity versus azimuth plot for each level

Derived Products

- Radial velocity versus azimuth plot
 - The VAD algorithm produces a plot of radial velocity as a function of azimuth
 - The ideal plot would appear as a sine wave
 - First, the VAD algorithm plots wind direction versus velocity as simple points on a velocity Vs azimuth axis
 - Secondly, the algorithm places a “best fit” sine-wave curve to the plotted data points

Derived Products

- Thirdly, the algorithm computes the Root Mean Square (RMS) of all the velocities located outside of the curve
 - » The actual radial velocities are scattered about the sine wave
 - » The RMS is the velocity difference between wind data points and the sine wave
 - » The further a velocity is away from the curve, the greater its RMS value
 - » The smaller the RMS the more accurate or reliable the velocity value
 - » After the RMS is calculated, the next step is to compute the offset

Derived Products

- To compute the offset, the amplitude of the sine wave is divided exactly in half by a line called the “zeroth harmonic”
- The distance between the velocity zero line and the zeroth harmonic is the offset
- The algorithm uses the offset to indicate the reliability of the curve
- It also can give an indication of convergence, divergence, confluent and diffluent velocity at a given altitude

Derived Products

- Algorithm Limitations
 - Non-uniform Winds
 - » The VAD collects its velocity data from a series of levels or planes
 - » Each elevation slice samples a plane
 - » The VAD analysis range (slant range) changes depending on the wind altitude levels selected for display on the VWP
 - » If the true wind is not uniform throughout the plane, the VWP winds may be incorrect

Derived Products

» Consider the following example:

- a. The VAD analysis range is 20 nm
- b. The wind flow at 20 nm west of the antenna is 270° at 40 knots
- c. The wind flow at 20 miles east of the antenna is 270° at 20 knots
- d. This would cause a bias, because of the non-uniform winds on each side of the RDA
- e. This example represents speed convergence
- f. This situation would be discernible on the VAD Plot product but not on the VWP itself

Derived Products

g. If the difference between the inbound and outbound flow is within acceptable parameters then an average wind speed is reported

h. However, if the difference exceeds the pre-determined symmetry threshold for the algorithm, winds for this layer would not be reported

Derived Products

- Algorithm Thresholds
 - Like other algorithms, the VAD algorithm contains several adaptable parameters from which the UCP operator can establish threshold values
 - Some parameters establish thresholds not to be exceeded, while others establish minimum values, which must be met or surpassed
 - If these thresholds are not satisfied during algorithm processing, the result may be that no wind data are reported for that particular altitude
 - When this happens, an “ND” is displayed for that altitude on the VAD Winds Profile

Derived Products

- Insufficient amount of scatters
 - In order for the weather radar to receive information about atmospheric phenomena, there must be a sufficient amount of scatters available in the region being sampled
 - In very dry air above the boundary layer, there may be an insufficient amount of scatters available to produce VAD data
 - This is another instance where “ND” is displayed

Derived Products

- Product Description

- The VAD Wind Profile (VWP) shows the radar operator wind velocities at various altitudes above the earth in 1000-foot increments
- The VWP provides a time-height profile of VAD derived winds similar to a series of Skew-T diagrams
- Availability
 - VAD: Several products per volume scan with 8 data levels ranging from ND - 50 knots
 - VWP: One product per volume scan with 5 data levels ranging from 0-16 knot RMS

Derived Products

- Presentation
 - VAD: Graphic plot of mean radial velocity versus azimuth angle
 - The best-fit sine wave is overlaid on the plot of the velocity points
 - VWP: Graphic display of up to 11 vertical wind profiles
 - Wind shafts are used to indicate direction, barbs are used to indicate speed and color is used to indicate RMS
 - Up to 30 different altitudes can be displayed on each vertical wind profile

Derived Products

- Resolution and Coverage
 - From 1,000 feet to 70,000 feet in height, with a minimum altitude interval of 1,000 feet
 - Up to 30 height levels and 10 previous volume scans can be displayed
- Product legend is on the right side; the maximum wind from all 30 levels is listed

Derived Products

- Limitations

- Displayed wind estimates are biased when actual sampled wind fields are non-uniform; I.e. convergence, divergence over the radar site
- Whenever the sampled data fails any of the internal algorithm thresholds, “ND” (no data) is displayed
- In very clear air above the boundary layer, an insufficient amount of scatters may be present for reliable returns

Derived Products

- Mesocyclone Product (MESO)
 - The Meteorology of Mesocyclones
 - Mesocyclones are areas of strong localized cyclonic rotation found in severe supercell thunderstorms (not all mesocyclones produce tornadoes)
 - The strongest mesocyclones form when strong vertical wind shear is present in the environment
 - These strong shear mesocyclones are often observed in the central U.S. with only a few observations in the eastern part of the country

Derived Products

- Mesocyclones in Strong Vertical Wind Shear
 - Strong shear mesocyclone signatures of supercell storms have a core diameter of 3 to 9 km, a maximum tangential velocity of 20 m/s or greater, and time and height continuity
 - Results from the Joint Doppler Operational Project (JDOP) indicated that roughly 50% of identified mesocyclones produce tornadoes, while 95% are associated with some form of severe weather
 - The vortex is first detected at the mid-level of the storm and with time, it lowers toward the ground, as well as builds upward
 - Only 2% of observed mesocyclones are anticyclonic and they do not usually produce tornadoes

Derived Products

– The Mesocyclone Algorithm

- The mesocyclone detection algorithm is designed to assist you in identifying in-storm circulation's for the purpose of forecasting severe weather events
- To efficiently use this valuable product, a basic understanding of how the algorithm works is necessary
- The mesocyclone detection algorithm locates mesocyclones through a pattern recognition technique
- Using base velocity data, this algorithm searches for symmetric regions of large horizontal shear
- After detection of these horizontal features, it attempts to correlate them vertically

Derived Products

- Determination of features
 - Uncorrelated shear (UNCO) – those 2-D features not linked with other features from different elevation slices
 - 3-D correlated shear (3DCO) – those features linked vertically but DO NOT meet size and symmetry criteria for a mesocyclone
 - Mesocyclone (MESO) – those 3-D features that meet or exceed the mesocyclones size and symmetry criteria

Derived Products

- Product Description
 - The mesocyclone product provides you with information about the presence and nature of rotating fields associated with severe thunderstorms
 - It accomplishes this by identifying wind shears within storm bearing clouds

Derived Products

- After identifying these wind shears, it groups them into three different features:
 - 3DCO (three dimensional correlated shear) - an area of shear which has vertical consistency, but is not symmetrical in the horizontal
 - UNCO (uncorrelated shear) - which is a significantly large area of shear having horizontal symmetry but not vertical consistency
 - MESO (mesocyclone) - which is significantly large, has horizontal symmetry and is vertically consistent
- One product is available per volume scan

Derived Products

- Product display is in three forms
 - Alphanumeric table of values
 - Graphic display of symbols at computed positions
 - Mesocyclone symbol - thick open yellow circle with associated storm ID and is proportional to the diameter of the feature and has pixel priority if displayed over other products
 - 3-D correlated shear - thin yellow circle, one pixel in width, with no storm ID and is proportional to the diameter of the feature and also has pixel priority
 - Uncorrelated shear - no symbol available; identified in the alphanumeric product only

Derived Products

- Graphic overlay for use with other products
- Product legend is on the right side, in full or quarter screen format
- If no mesocyclones are detected, the product will display “NO MESOS” in big bold letters

Derived Products

- Limitations

- Range

- Optimum effective range

- » Although velocity data is processed up to 124 nm, the optimum effective range of the mesocyclone algorithm is approximately 65 nm

- » This range limitation is due to beam broadening

- » At far ranges, resolution is not fine enough to measure small scale circulation

- The WSR-88D does not process velocity data within .54 nm of the radar site

Derived Products

- MESO algorithm will not identify mesos beyond 110 nm due to the max height threshold of 8 km
- Product range
 - » The MESO product has a range of 124 nm
 - » However, the product only identifies UNCO past 110 nm

Derived Products

- Data quality
 - Several data quality errors can contaminate the Mesocyclone algorithm by tricking it into thinking that a feature exists when in reality it doesn't
 - Also, the contamination may mask significant data which could cause the WSR-88D to ignore an area of rotation
 - The two data quality problems are from range folded data (which can mask a feature) and aliased data (which can trick the WSR-88D into thinking something actually exists)

Derived Products

- Scan strategies
 - Since vertical continuity is required for mesocyclone detection, improper sampling may cause the algorithm to discard a significant feature
 - Two examples of this are: data gaps that are especially prevalent in VCP 21 and the cone of silence at near ranges (< 20 km)

Derived Products

- Time continuity
 - Mesocyclone detection algorithm does not establish time continuity, this is left up to the operator
 - Time continuity must be established to determine what stage of development the mesocyclone is in

Derived Products

- Use of the Mesocyclone product
 - Increased severe thunderstorm warning lead time due to the ability of the WSR-88D to alert us to in-storm circulations
 - However, the mesocyclone product should never take the place of an effective metwatch
 - The Mesocyclone product is a tool which could alert you to increase your metwatch in the affected area

Derived Products

- Tornado Detection Algorithm (TDA)
 - Theory of the Tornado Detection Algorithm
 - The tornadic vortex signature (TVS) is a small-scale, abnormal region of high shear that is associated with a tornado
 - A TVS is first detected by radar at the mid-levels of the storm and in time extends both upward and downward
 - It reaches the cloud base coincident with the appearance of the funnel cloud and, at low levels, overlaps the tornado's damage track
 - Joint Doppler Operational Project (JDOP) investigators noted that the TVS is detectable, on the average, 20 minutes prior to tornado touchdown (based on strong tornadoes located near the radar)

Derived Products

- Most TVS's are associated with tornadoes; however not all tornadoes produce a detectable TVS. The TDA is used to search for, and locate TVS's
- Tornado Detection Algorithm (TDA)
 - The TDA is modeled after the storm cell identification and tracking algorithm
 - It uses a three-step process to identify circulations, and works separately from the mesocyclone algorithm to identify areas of shear associated with tornadoes

Derived Products

- The TDA detects two phenomenon
 - Tornadic Vortex Signature (TVS)
 - » A Tornadic Vortex Signature is defined as a 3-D circulation with a base located on the 0.5° slice or below 600 meters ARL (above radar level)
 - » The depth of the circulation must be at least 15 km
 - » Additionally the maximum shear detected anywhere in the circulation must be at least 36 m/s ($\cong$ 72 knots) or at least 25 m/s ($\cong$ 50 knots) at the base of the circulation

Derived Products

- Elevated Tornadic Vortex Signature (ETVS)
 - » An Elevated Tornadic Vortex Signature is defined as a 3-D circulation with a base above the 0.5° slice and above 600 meters ARL
 - » The depth of the circulation must be at least 15 km
 - » Additionally, the delta velocity at the base of the circulation must be at least 25 m/s ($\cong$ 50 knots)
- The values just specified for TVS and ETVS are default values, and are only some of the TDA adaptable parameters

Derived Products

- Product Description
 - The TVS product provides you with both graphical and alphanumeric output on algorithm identified TVS's and ETVS's
 - This product can also be used as an overlay with other products
 - One product is available per volume scan
- Display
 - Alphanumeric table of values
 - Graphic display of symbols at computed positions
 - » TVS and ETVS are both displayed as an inverted red isosceles triangle
 - » The displayed triangles flash and have pixel priority
 - Graphic overlay for use with other products
 - The product legend is displayed on the right side in full or quarter screen format

Derived Products

- Use of the TVS product
 - Primary use of the TVS is to alert the user to suspect areas of rotation
 - The TVS product should not be used as a stand alone product but should alert the user to intensify their metwatch
 - Once the TVS product has identified a potential area, turn your attention to other products, such as velocity for further interpretation
 - The intent of the TVS product is to keep the forecaster on top of a severe weather situation when the workload is high

Derived Products

- Limitations

- Beam broadening may cause features to be missed or improperly identified, especially at ranges past 60 km from the radar
- Beyond 60 km, the TVS will most likely be triggered by a strong mesocyclone and, as experience has shown, not all mesocyclones produce a tornado
- Adaptable parameters need more research
- The default parameters may not be right for some locations and research should be conducted on their adaptability
- False alarms may result in an over-warning, or desensitizing of forecasters

Derived Products

- Parameters may need to be adapted to keep the false alarm ratio low
- The TDA tends to identify TVSs near the bend in a Line Echo Wave Pattern along the interface between warm moist inflow and storm outflow
- While many on the TVSs are false alarms, tornadoes do occasionally spin up under these conditions

Derived Products

- Recognizing when limitations may be a factor
 - When a TVS is reported by the TDA, consider the environmental wind and thermal profile, the signature's position in relation to the storm with which it is associated, time continuity, and the storm's range from the radar
 - Since the TDA works independently of the mesocyclone algorithm, the detection of a mesocyclone coincident with the TVS may support issuing a tornado warning
 - If the TVS is adjacent to a strong reflectivity gradient especially near the rear of the storm, near a notch, or near an appendage attached to the right rear quadrant of the storm, then the forecaster should give great consideration to issuing a tornado warning

Derived Products

- Severe Weather Analysis Products (SWA)
 - Theory of Severe Weather Analysis
 - The Severe Weather Analysis (SWA) Products contain the same information as the three base products
 - There is one significant difference and that is the SWA displays this information in the highest resolution available for each base moment, regardless of the range, to a maximum range of 124 nm
 - In addition, the Radial Shear Product is included in this package

Derived Products

- Display

- Each of the SWA products may be displayed separately in full screen format as a 27 x 27 nm window
 - The information in the product legend applies ONLY to that window
 - Unlike other products, heights are AGL instead of MSL
- Quarter Screen Format
 - All four of the Severe Weather Analysis Products are available in quarter screen format
 - This allows the operator to simultaneously view all three base moments, as well as the radial shear product

Derived Products

– Product Description

- The SWA product provides Reflectivity, Mean Radial Velocity, Spectrum Width, and Radial Shear in 27 x 27 nm areas at the highest resolution available
- Radial shear is unusable and is replaced by SRR
- Available upon user request (one time product request), or as an alert-paired product with those same data levels utilized by the base products

Derived Products

- Use of the Severe Weather Analysis Products
 - Primarily, the SWA is used to interrogate potentially severe convective storms
 - It allows the operator to examine all three base moments simultaneously in the highest resolution available
 - Features found in one product can be quickly correlated to features in another

Derived Products

- Limitations

- Beam Broadening occurs as the radar beam gets further away from the RDA, it becomes wider
 - Even though SWA is displayed in the highest resolution possible, small features will not be visible at long ranges due to this beam broadening
 - Beam broadening affects each product in a different way
 - » SWR Higher reflectivities may be averaged out, resulting in reduced values
 - » SWV Larger sample volume area may cause small scale features to be missed
 - » SWW Larger sample volume area increases the likelihood of variance, resulting in higher values

Derived Products

- Display Limitations
 - The SWA products are only available in 27 x 27 nm windows
 - This makes it necessary to use the base products to view large scale features
- Elevation Limitations
 - The SWA products are only generated for the elevation angle requested
 - Since severe storm analysis requires height continuity, multiple requests must be made
- Base Product Limitations. All limitations that apply to Base products also apply to SWA products

Derived Products

- Cross Section Products
 - Cross section theory
 - Cross section products provide a vertical cross section of one of the base moments (REF, VEL, SW) as a graphical image along a user defined vector; the plane is on a height versus distance axis
 - This is accomplished by mapping the nearest value from the current volume scan for each point in the plane, then performing linear interpolation to fill in the gaps

Derived Products

- Product Description
 - Cross section products are only available for display in full screen format
 - The legend provides information on:
 - Current date/time
 - Product name/ID number/mnemonic
 - Product date/time
 - RDA, its location and elevation
 - Mode/VCP
 - Western most user selected end point/eastern most user selected end point
 - Product display state, status, and alert areas (the same as in other products)

Derived Products

- In the product display area, the following supplemental information is also provided
 - Above the product, the maximum data level(s) is/are displayed
 - » Reflectivity cross section, the maximum dBZ is displayed
 - » Velocity cross section, the maximum inbound/outbound Velocity is displayed
 - » Spectrum Width cross section, the maximum Spectrum Width is displayed
 - » In all three instances, the altitude at which the maximum values were found, and the AZRAN from the RDA are displayed above the product for clarification

Derived Products

- Below the product, you will find the AZRAN locations (from the RDA) for which the cross section was built
 - » West to East oriented cross section
 - a. The western most user selected point, mid point, and eastern most point will be listed below the product
 - b. The mid point is calculated by the NEXRAD
 - c. West to East cross sections will always be viewed with western most side on the viewer's left

Derived Products

- » North to South oriented cross section
 - a. The northern most users selected, mid point and eastern most point will be listed below the product
 - b. North to South oriented cross section will always be viewed with the northern most side on the viewer's left
 - c. The vertical axis is labeled 0 to 70 in thousands of feet
 - d. The horizontal axis is labeled in 5, 10, or 15 nm increments, depending on the user-selected length of the Cross Section

Derived Products

- Range and Resolution Combinations
 - Resolution is always .54 nm in the horizontal and .27 nm in the vertical
 - Range can vary from 1 to 124 nm depending on the operator selected end points
 - Both points must be within 124 nm of the RDA
- Data levels are the same as in the base product which corresponds to the cross section requested

Derived Products

- Cross section points
 - Cross section products provide a vertical cross section of the particular base moment on a height (in the vertical) versus distance (in a horizontal) axis
 - The end points of this axis are PUP operator defined and can be up to 124 nm apart
 - Both points must be within 124 nm of the RDA
- Available upon user request (one time product request), this product will not be available as an alert paired product
- Presentation is in full screen format only
- Resolution and Coverage
 - The resolution is .54 nm horizontally by .27 nm vertically
 - The products will display up to 70,000 ft in the vertical and as much as 124 nm in the horizontal

Derived Products

- Use of cross section products
 - Primarily, the cross section products are used to examine the vertical structure of potentially severe storms in all three moments
 - However, they are also useful in determining important meteorological information during non-convective, even clear air events

Derived Products

- Reflectivity cross sections
 - Clear air mode uses
 - » Using a reflectivity cross section, the operator can determine the depth of the moist layer by analyzing the vertical extent of scatterers
 - » Frontal slope
 - » Cloud bases and tops
 - Precipitation mode uses
 - » Weak Echo Regions and Bounded Weak Echo Regions
 - » Location of the maximum reflectivity core
 - » Hail spikes
 - » Reflectivity gradients, mid level overhangs, max top position

Derived Products

- Velocity Cross Sections
 - Velocity Cross Section in Clear-Air Mode
 - » Turbulence
 - » Boundary Layer
 - » Frontal slope may be easier to determine on the Velocity Cross Section
 - In precipitation mode, all the uses found in clear air mode apply and the following phenomenon are also evident:
 - » Rotational Wind Fields (mesocyclones, TVSs)
 - » Divergence/Convergence

Derived Products

- Spectrum Width Cross Section
 - Clear Air Mode
 - » In clear air mode, Spectrum Width Cross Sections are used in conjunction with velocity cross sections to analyze turbulence and boundaries
 - » Correlation of high Spectrum Width values to velocity features reinforces the case for turbulence, or the existence of a boundary
 - Precipitation Mode
 - » Verify rotational flow fields
 - » Freezing level

Derived Products

- Limitations

- Echo Characteristics

- Values mapped on the Cross section products may be from birds, insects, clouds, precipitation, or any number of scatterers
- These targets affect velocity and spectrum width values the most

- Limitations by range

- Both end points must be within 124 nm
- Beyond 124 nm, the lowest elevation angle is so high that the lower component of storms aren't sampled anyway

Derived Products

- Beam Broadening affects all three cross section products differently
 - Reflectivity at long ranges are reduced and gradients may not be visible
 - Velocity maxima and minima are also reduced, small features such as TVS may not be visible
 - Spectrum width values are likely higher due to beam broadening as a larger sample volume has a higher likelihood of variability
- Cross section orientation
 - Velocity Cross Sections must be cut parallel to the radials for divergence/convergence
 - Velocity Cross Sections must be cut perpendicular to the radials for rotation

Derived Products

- Interpolation
 - Cross section products do not interpolate from the lowest elevation angle to the surface or above the highest elevation angle
 - This results in a stair stepped display

Derived Products

- Storm Cell Tracking/Position Forecast (STI) Product
 - Storm Cell Tracking
 - Storm Cell Tracking monitors is the movement of storm cells by matching cells found in the current volume scan to the cells from the previous volume scan
 - If the algorithm is unable to correlate a centroid with a centroid from the previous volume scan, it labels the storm as “NEW” and does not forecast a track

Derived Products

- Storm Position Forecast
 - Storm Position Forecast predicts the future centroid location of storm cells based on a history of the storm's movement
 - The algorithm uses an identified cell's previous movement over several volume scans to output a forecast movement up to 60 minutes in the future
 - The length of a forecast (0, 15, 30, 45 or 60 minutes) is based on the accuracy of the previous volume scan's forecast

Derived Products

- Product Display
 - Graphics Product
 - Data developed by the SCIT algorithm is directly input to the Storm Track Information (STI) Product
 - This product displays up to 100 storms' past, present and future locations
 - Graphics Display
 - » The current position will be displayed as a circled "X"
 - » Past positions are displayed as a solid dot
 - » Future positions are displayed as an "X"
 - » Cells with movement of less than the minimum specified speed (default = 5 knots) are circled, indicating little or no movement

Derived Products

- The STI Attribute Table
 - » Appears at the top of the STI product (color coded cyan)
 - » Contains information on all identified cells
 - » The table lists the cells in order of Cell based VIL from left to right, and consists of:
 - a. The Storm ID
 - b. Storm location
 - c. Forecast movement (the direction is in degrees from)
 - d. Tracking error
 - e. Maximum dBZ value and its height
 - f. On the first volume scan a storm is identified, the word “NEW” is placed on the line representing forecast movement

Derived Products

- Applications

- The STI product is best viewed as an overlay, and the algorithm performs best on well-defined isolated storms
- The SCIT algorithm shows a high degree of skill in identifying distinct individual cells occurring in lines or clusters
- This ability to identify individual cells leads to better tracking and forecast results
- Better storm identification leads to better cell attribute calculations and an improved Hail Index product

Derived Products

- Limitations

- If stronger reflectivity values exist in a storm above the lowest component, the algorithm may mis define that component as the lowest component
- This would cause a misinterpretation of the storms overall mass and would affect other algorithm calculations
- When in VCP 21, large errors may occur in the cell attributes of storms
- Storm calculation can be adversely affected by what the radar is not sampling in the data gaps associated with this VCP

Derived Products

- Hail Index (HI) Product
 - Graphics Product
 - The Hail Index graphics product presents several symbols
 - The probability of hail (POH) is identified with a small, open or solid green triangle
 - Whether the triangle is open or solid depends on a “fill-in” threshold set by the PUP operator for a specific percentage of occurrences (covered in the manager’s section)
 - The probability of severe hail (POSH) is represented by a larger, open or closed green triangle
 - POSH also depends on a “fill-in” threshold

Derived Products

- The maximum expected hail size (MEHS) is displayed in the center of the POSH symbol rounded to the nearest inch from 1 to 4
- If a storm has hail identified that is less than $\frac{3}{4}$ inch, than an asterick (*) is placed in the center of the POSH symbol
- The Hail Index Attribute Table, colored in green, is available at the top of the graphics product
 - The table lists: Storm ID, AZRAN, and POSH, POH, MEHS (to the nearest $\frac{1}{4}$ inch)
 - Also, the altitudes of the 0°/-20° temperatures and the date/time at which the information was last updated
 - Each page of the table can contain up to 6 storms
 - Cells are ordered by POSH first, the by POH

Derived Products

- Alphanumeric Product
 - The Hail Index alphanumeric product is available via the applications terminal
 - The product display includes: Storm ID, POH, POSH, and MEHS (rounded to the nearest $\frac{1}{4}$ inch)
- Applications
 - The hail detection algorithm (HAD) has shown a very high probability of detection of cells that contain severe hail, especially greater than 1 inch
 - While false alarms may be a limitation, the display parameters are adaptable at the PUP, and local adjustments to thresholds may reduce false alarms

Derived Products

- Limitations

- The HAD needs accurate and timely measurements of the MSL altitudes for the 0°C and -20°C levels
- Failure to update this information will degrade the algorithm's performance
- In limited operational use, the POSH and MEHS have tended to overestimate the chances and size of hail in weak wind and tropical environments
- The accuracy of the hail estimates partially depends upon the accuracy of the cell component information provided to the algorithm

Derived Products

- Cell Trends Display
 - Cell trends is a graphic display that gives up to a 10 volume scan history of parameters from algorithm identified storm cells
 - Cell trends is not an actual product. It has no product ID number or mnemonic
 - Cell trends cannot be archived; however, it can be generated from an archived Storm Structure product
 - Cell trends can only be generated from the graphics table

Derived Products

- Presentation Format
 - The Cell trends display contains four separate quadrants and a legend area
 - The information contained in the quadrants is as follows:
 - Upper Left Quadrant: Storm Top/Base (ARL), height of the centroid, and height of maximum dBZ
 - Upper Right Quadrant: Probability of Hail and Probability of Severe Hail
 - Lower Left Quadrant: Cell based VIL
 - Lower Right Quadrant: Maximum reflectivity
 - Legend area: Storm ID#, AZRAN, graphical plot of cell location, and volume scan times included in trend data

Derived Products

- Use of Cell Trends

- Cell trends provides continuity on individual storm cells over a period of time
- By tracking the increase or decrease of storm tops, maximum reflectivity values, and cell-based VIL, you'll have a better idea of what to expect from storms in the area
- The Cell trends display provides an effective way of determining the life cycle of convective development
- You can also determine the status of supercells and the potential for microbursts
- After a weather event occurs, the Cell Trends display may be used for post storm analysis

Derived Products

- Limitations

- The volume coverage pattern employed has a direct impact on the Cell Trends display
- VCP 21 has fewer slices, resulting in more variability of displayed data
- Range to the cell is another concern when using the Cell Trends display
- At far ranges, data may be unreliable due to the cell being sampled by only the lowest elevation slices
- Storm cell bases will be overestimated
- Cells in close proximity to the RDA, may be affected by the cone of silence, resulting in the mid and upper levels of the storm not being sampled

- APPLICATION: Throughout the entire lesson
- EVALUATION: Administer A-501c now and the Written Test at the end of the unit